

# The Journal of Undergraduate Research

---

Volume 9 *Journal of Undergraduate Research*, Volume  
9: 2011

Article 21

---

2011

## Xenakis' Combination of Music and Mathematics

Janelle Anderson  
*South Dakota State University*

Follow this and additional works at: <http://openprairie.sdstate.edu/jur>



Part of the [Composition Commons](#), and the [Other Mathematics Commons](#)

---

### Recommended Citation

Anderson, Janelle (2011) "Xenakis' Combination of Music and Mathematics," *The Journal of Undergraduate Research*: Vol. 9, Article 21.  
Available at: <http://openprairie.sdstate.edu/jur/vol9/iss1/21>

This Article is brought to you for free and open access by Open PRAIRIE: Open Public Research Access Institutional Repository and Information Exchange. It has been accepted for inclusion in The Journal of Undergraduate Research by an authorized administrator of Open PRAIRIE: Open Public Research Access Institutional Repository and Information Exchange. For more information, please contact [michael.biondo@sdstate.edu](mailto:michael.biondo@sdstate.edu).

# Xenakis' Combination of Music and Mathematics

Author: Janelle Anderson  
Faculty Advisor: Professor Walsh  
Department: Music Literature and History III

## ABSTRACT

My interest in using mathematics in music composition stems from the works of the contemporary composer Iannis Xenakis. As a physics and music education major I am able to combine both fields of study for this topic. Although Xenakis wrote many orchestral compositions it is his vocal music that I have concentrated on as I too am a singer. Graphic representation and new music notation are among the methods used to analyze his music.

I found that his first choral work was called "Nuits," which I proceeded to analyze. I also found myself interested in the analysis of a more recent piece "Sea Nymphs" as another example of his style. I found Xenakis' graphical and musical notation intriguing especially related to the evolution of music and mathematics throughout history. I found enough sources and his works in books, websites, song tracts, and documents. I have concluded that Xenakis' style of writing vocal works may not thrive, but his instrumental works and composing methods will surely withstand the test of time.

## XENAKIS' COMBINATION OF MUSIC AND MATHEMATICS

Since the beginning of life, evolution has evoked change in various species throughout generations on planet Earth that advance life on this planet. I believe Homo sapiens have made the most notable advancement of all, especially in intellect. The heterogeneous content that humans have become familiar with in the intellectual field are numerous, therefore, one person cannot be a master of all subjects, but the interlay of content is most interesting, specifically, in mathematics and music. Iannis Xenakis has explored these subjects in connection with his music compositions. Specifically, his vocal compositions are creative combination of mathematics and music that have evolved from the demand for advancement in vocal performance and in musical notation.

According to A.S. Barthel-Calvet's biography of Iannis Xenakis, this famous composer, was born May 24, 1922 in Braila Rumania. His mother was Photini Pavlou, his father was Clearchos Xenakis, and he had two brothers. Xenakis was introduced to world music because his mother was trilingual; therefore, she knew of other places, and she was a pianist/flutist which brought music into his life from a very young age. In 1932 he moved to Greece. In 1941 Xenakis joined the communist Greek resistance. January 1, 1945 shrapnel hit Xenakis in the face, and he was left for dead by his comrades, but his father found him

and brought him to the hospital. In 1949 Xenakis begins composing music, and he continued with music and architecture until his death February 4, 2001. (Barthel-Calvet)

## HISTORIES IN TANDEM

Music and mathematics have evolved together throughout time. According to Oliver Messiaen, in five hundred BC there is evidence of the beginning of both subjects; music began with creation of music theory using geometry and incomplete scales; math discovered natural numbers and fractions (Messiaen, 1994). In other words, humans were beginning development in higher thinking academic subjects, but these subjects relate so closely that when humans begin development of one, the other follows.

Similarly, according to A. Helden, Galileo Galilei's father, Vincenzo Galilei, was a musician, and he conducted experiments during the 1500s by hanging double bass strings from the ceiling connecting weights to the end, then plucking the string and counting the number of revolutions per period of time (Helden 2005). Today musicians do not use science like this, but today there are scientists with emphases in mathematics and not music. It is also interesting that Galileo Galilei, a musician's son, became one of the best-known scientists of his time; this contributes to the connection of the subjects of math and music in history.

Messiaen also connects the subjects in 1700AD-1800AD; musical forms such as the fugue and sonata appeared while mathematicians invented complex numbers and group structures as well as defined continuity (Messiaen 1994). Both of these developments involve groupings, structures, and inventions that are almost identical, yet in different subjects. Continuity was most intriguing to Xenakis, so much so, that he graphically represented continuity with the musical glissando. A glissando is a continuous slide between two notes. Trombones are known for performing glissandos well.

## GRAPHICAL REPRESENTATION OF MUSIC

Xenakis makes the content of math and music belong together with graphic representation, and Xenakis points out the development throughout time of music and mathematics in his book *Formalized Music*. This book discusses many of his various discoveries and experiments, including graphs involving the glissandi. There are graphs of the song *Metastaseis*'s glissandi in many books including Barbara Hanning's text book *Concise History of Western Music* (p. 644). *Metastaseis* is of great importance due to its graphical shape being based off of the architectural structure of Philips Pavilion's surfaces creating structured glissandos (Messiaen, p. 62). Another popular Xenakis graph is the *Free Stochastic*. It is my opinion that many articles do not thoroughly explain what these graphs mean; Xenakis breaks the graphs down in *Formalized Music*. The best way to explain what is happening in these graphs is to break it down into smaller graphs. The smallest part of a graph is a point, and points are described using the axes. The axis that is used for the glissandi graph is pitch vs. time.

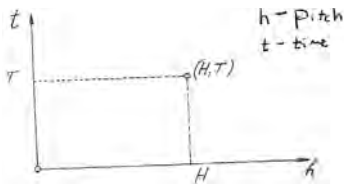


Figure 1. Graph information found in *Formalized Music* p. 212

This concept seems simple enough, but what if we look at a bigger piece such as straight lines. The graph below is a small complete section of a diagram for music in time.

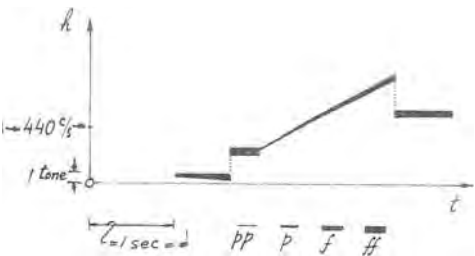


Figure 2. From *Formalized Music* p. 213

N	T	H	V	D	I
1	1.00	1	0	0.66	3
2	1.66	6	0	0.33	5
3	2.00	6	+17.5	0.80	6
4	2.80	13	0	?	5

N = note number

H = pitch in half tones with + 1 0 ~ A ~ 440 Hz

V = slope of glissando (if it exists) in semitones/sec, positive if ascending, negative if descending

D = duration in seconds

/ = number corresponding to a list of intensity forms

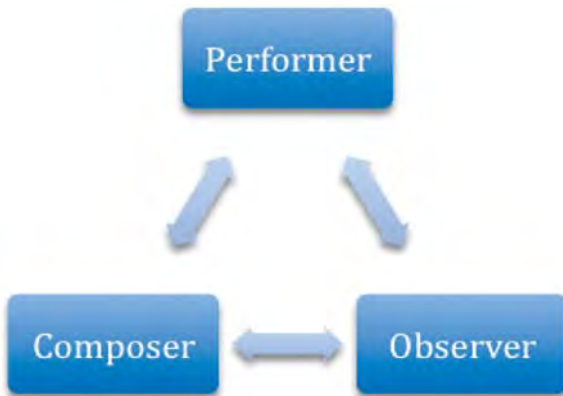
The pitch is on the y-axis with a reference frequency of 440Hz, and there is an indication of intervals. The x-axis is simply time with a quarter note tempo of 60. The graph shows a key at the bottom with line width matched to dynamic marking. Obviously every line with a slope of zero is a particular pitch, and there is no connection between pitch one and two. The dotted line represents discontinuity. Then the third line with a slope of +17 represents a glissando, continuity is present between all of these notes. This glissando is in a positive direction meaning that the pitch is getting higher and the thickness of the line increases suggesting a slight crescendo. Then discontinuity appears again in the fourth note and there is no end; therefore, no final time can be determined of the fourth note. (Figure 2 Graph is from *Formalized Music* p. 213)

## THE HUMAN VOICE

Xenakis views the human voice differently than many other composers because he searches for pure vowels, he feels that the composer is at the mercy of the performer, and he believes the voice is an instrument and should be treated as such.

Many composers of vocal pieces search for the purest vowel, which is difficult to do since singers have to modify vowels depending on the register they are using (Ware, 1998). Xenakis used sounds without meaning, *Anemoessa*; he decided to do this because he felt that Germans are the only people who pronounce consonants strong enough to understand the words and the meaning of the words (Varga, p.105). While analyzing the English song *Sea Nymphs*, an a cappella piece with 24 voice parts, an English speaking person would notice that the phrases are not particularly coherent. Xenakis accomplishes this by using phonemes from Shakespeare's *The Tempest*. He creates a scattered affect by placing the phonemes randomly. Obviously, he was not interested in storytelling as other vocal composers such as Benjamin Britten are (Groves, 2001).

Xenakis believes that the composer is at the mercy of the performers, and that new music usually is misinterpreted at first (Varga, p.106). There is a great deal of dependence that the composer has on the performer, but the performer also has a dependence on the composer as can be seen in Figure 3 from *Basics of Vocal Pedagogy* p. 234. Without the composer, the performer, and the audience members, there would be no performance art. Ware shows all pieces of this phenomenon are crucial to maintain and advance musical in a society in Figure 3.



**Figure 3.** Recreated from *Basics of Vocal Pedagogy* p. 234

Xenakis also believes that in order for performers to interpret his music correctly they need a better understanding of science (Varga, p.126); musicians need to be more rounded and intelligent. Public education in industrialized countries is getting better, and students are becoming more well-rounded with many subjects through high school. There are no longer people who are only trained in one craft. For Example, a blacksmith would not know how to

read, just as a scholar would not know how to make swords. Industrialized countries have not only higher literacy rates, but also mathematical, scientific, and political understanding. Though somehow there is not crossing between analytical and creative thoughts according to Xenakis, "Even in the United States, with all its technological advantages, scientists simply lack imagination in a field which lies outside of mathematics or physics." (Varga p.76) Performers and composer should be able to do more than just perform and compose just as mathematicians and physicists need to be able to do more than math and problem solving. Hopefully, this combination of fields can be achieved without too much pain from either analytical or creative thinkers.

It is rare that the human voice is expected to do strenuous music that could injure the performer such as pizzicato. If a vocalist does not use vibrato, there is stress on the vocal mechanism, and pizzicato is hard for a vocalist to do due to the glottal approach necessary to create the sound. These practices are not healthy, but Xenakis uses both of these in his works. Xenakis believes that the human voice is an instrument and should be treated as such (Varga p.105). The reason the human voice requires fewer articulation markings is that feeling is expressed with interpretation and acting. Singers have to visually show expression with acting (Ware, p. 233). Instruments require more rigorous articulations and expressions because there is not as much acting/facial expression possible with most instruments. A clarinetist is not able to give a big toothy smile while sustaining a note to express mischievousness, but the clarinetist can play the note in a more playful manner perhaps with a trill, or another articulation that vocalists do not usually execute.

Xenakis also specifies in his work *Nuits* that the performer is "absolutely without vibrato." Disregarding vocal ability and health with vibrato is a common mistake for old-school choral enthusiasts. According to Ware:



Voices lacking vibrato are usually described as breathy, dull, straight, spread, or yell-like. One explanation of the vibrato-less (straight) tone is that intrinsic laryngeal muscular tension causes the mechanism to be rigid or static instead of the relaxed and flexible condition necessary for proper vibrato functioning...excessive straight-tone singing can retard the vocal development of young singers, studio voice teachers are often in conflict with choral director over this practice... vibrato actually results in an improved choral sound that is characterized by truer intonation, balanced coral tone, and more variable dynamic contrasts. (Ware, p. 182)

However, Xenakis does not use vibrato to successfully emulate his mathematical idealism. If the pitch is altering a quartertone on either side of the core pitch the frequency numbers do not add up to his graphical representations or the mathematical equations. This could prove to be a problem in popularity if his musical style leads performers to hurt themselves while performing the work.

## NEW NOTATION IN *NUITS*

Due to the new exploration/definition of vocal ability Xenakis created new notation to aid his compositional combination of music and mathematics as can be seen in *Nuits*. When

a person listens to the piece *Nuits* it could easily be interpreted as Halloween music, not high level art, even Xenakis himself understands this, "I realized that probabilities used wrongly could be boring..." (Varga p.79) Xenakis also mentions his scientific friends not understanding his work aurally, only visually or mathematically. (Varga, 1996) It is my opinion that with time and intelligence people may one day understand the works of a idea on both levels, aural and visual, without a book explaining the equations.

*Nuits* is a most intriguing piece today, and it requires new notation that Xenakis created. There are many instructions at the beginning of the piece as well as International Phonetic Alphabet (IPA) symbols to explain the particular sounds he wants to be made. There is a key with symbols for the quarter steps because western music only writes the smallest interval as a half step. Many parts of the score are obviously hand written because music notation software does not have these symbols. The piece is in cut time with the half note equal to 60, and there are three vocal parts inside each part adding up to twelve different voices, while most vocal scores only go up to eight voices. Glissandos and quartertones dominate the first twelve pages of the music. Page twelve becomes very rhythmic, utilizing triplets, pentalets, and staccatos. Not all of the rests are written in, and Xenakis starts introducing non-traditional musical elements to the piece. Vocal shouts are written with percussion note-heads with an x. In measure 124 vocal tremolos are introduced. The next new symbol Xenakis uses in the piece is circles with little stems shooting out the side. According to the score, these "raise the pitch sufficiently in order that this voice produces  $\frac{1}{3}$  beats (interferences) with the other one as many per second as indicated by numerals." (Nuit, 1965) Candy cane shaped hooks are introduced later some pointing positively and others pointing negatively   meaning ascending/descending glissandi with extinction (very short, of an octave range approximately) respectively. A nasal pizzicato/glissando occurs in measure 136 for the women followed by the men whistling. The time of glissandos are indicated with numbers and arrows. In measure 160 all of these elements seem to be moving together and die out by measure 169. The beginning feeling and notation returns with tremolos until measure 179 when the score states, "Ataxic clouds on the syllable Tsi very sharp and dry" emerges. This is notated with dots all over the staves. The soprano "cloud" becomes a whisper then the men have "Ataxic clouds of the syllable Tsi whispering (voiceless even when varying the nuances and the timbre (sharp))" while the altos continue the quarter-tone glissandos. These concepts continue until the final three pages when there is little movement and a huge contrast from the rest of the piece is introduced. The singers all sing whole notes on varying quartertones. The very last sound you hear in the song is from the basses giving a single cough.

## CONCLUSION

In conclusion, it is my opinion that Iannis Xenakis will have a place in the history books; however, I do not foresee his vocal compositions ever becoming popular because of his disregard for vocal health and his lack of story and expression in these compositions. After all evolution involves natural selection, and his vocal works will die and his instrumental works will live on. Even though his vocal compositions do creatively combine mathematics and music to demand an evolved intelligent vocal performance, he disregards the delicacy of

the singers' instrument. Also, amateur listeners love stories; especially, when the vocal performers can act out the story. Expression with the human voice is not as aurally noticeable as it is with instruments. Vocalists express through acting and feeling, not mathematics. The reason I feel he will be in the history books is that his mind is in the right place combining music and mathematics. I see his instrumental works different from his vocal works because these pieces will last through the ages, because of the concepts and difficult meter and creative notation. The factor preventing his vocal pieces from extending to the future is his lack of respect for vocal health.

## REFERENCES

- A Twentieth-Century Musical Chronicle: Events 1900-1988 (Music Reference Collection)*. 1st ed. New York: Greenwood Press, 1989. Print.
- Barthel-Calvet, A. (n.d.). *Chronology*. (Friends of Iannis Xenakis Association) Retrieved December 10, 2010, from <http://www.iannis-xenakis.org/xen/bio/bio.htm>
- DeLio, Thomas. "Xenakis." *Perspectives of New Music* 39.1 (2001): 231-243. JSTOR. Web. 26 Sept. 2010.
- Godfrey, Daniel, and Elliott Schwartz. *Music Since 1945: Issues, Materials, and Literature*. 1 ed. Reston: Schirmer, 1993. Print.
- Grove, Sir George. "Benjamin Britten." *The New Grove Dictionary of Music and Musicians*. 2Rev Ed ed. New York, NY: Grove Publications, 2001. Print.
- Grove, Sir George. "Iannis Xenakis." *The New Grove Dictionary of Music and Musicians*. 2Rev Ed ed. New York, NY: Grove Publications, 2001. 605-612. Print.
- Hanning, B. R., & Grout, D. J. (2006). *Concise history of western music* (3rd ed.). New York: W.W. Norton.
- Harley, James. "Still Rich and Strange." *The Musical Times* 137.1845 (1996): 9-15. JSTOR. Web. 26 Sept. 2010.
- Helden, A. V. (n.d.). Vincenzo Galilei (ca. 1525 - 1591). *The Galileo Project*. Retrieved November 15, 2010, from [galileo.rice.edu/fam/vincenzo.html](http://galileo.rice.edu/fam/vincenzo.html)
- Iannis Xenakis. (n.d.). *Iannis Xenakis*. Retrieved November 23, 2010, from <http://www.iannis-xenakis.org/xen/read/listen.html>
- Lunsford, A. A. (2008). *The St. Martin's Handbook* (6th ed.). Boston, MA, USA: Bedford/St. Martin's.
- Messiaen, Iannis Xenakis; Olivier. *Arts-Sciences: Alloys (Aesthetics in Music Series; No. 2)*. New York: Pendragon Pr, 1994. Print.
- Modernism and Music: An Anthology of Sources (Chicago (Barthel-Calvet) History of American Religion)*. 1 ed. Chicago: University Of Chicago Press, 2004. Print.
- Prendergast, Mark. *The Ambient Century: From Mahler to Trance: The Evolution of Sound in the Electronic Age*. New York: Bloomsbury USA, 2001. Print.
- Ross, Alex. *The Rest Is Noise: Listening to the Twentieth Century*. New York: Farrar, Straus and Giroux, 2007. Print.
- Simms, Bryan R.. *Music of the Twentieth Century: an Anthology*. 2 ed. Reston: Schirmer, 1996. Print.



- Slonimsky, Nicolas. *Supplement to Music since 1900*. New York: Scribner, 1986. Print.
- Varga, Balint Andras. *Conversations With Iannis Xenakis*. Oxford: Faber & Faber, 1996. Print.
- Wadhams, Wayne. *Dictionary of Music Production and Engineering Terminology*. New York: Schirmer Books, 1988. Print.
- Ware, C. (1998). *Basics of vocal pedagogy: the foundations and process of singing*. New York: McGraw-Hill.
- Xenakis, Iannis. *Formalized Music: Thoughts and Mathematics in Composition*. Bloomington: Indiana University Press, 1972. Print.
- Xenakis, Iannis. *Music and architecture: architectural projects, texts, and realizations*. New York: Pendragon Press, 2008. Print.
- Xenakis, I. (1968). *Nuits*. Paris: Editions Salabert.
- Xenakis, I. (1994). *Sea nymphs: pour choer mixte, for mixed chorus*; (1994) ([Partitur] ed.). Paris: Salabert.